

## The molecular cloud content of early type galaxies P.3

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## 1. Introduction

A survey of the CO content of early type galaxies has led to 24 new detections, mostly lenticular galaxies. The galaxies, which are situated in both the northern and southern hemispheres, have been selected as being far-IR luminous compared to their blue luminosity, and situated at distances less than about 50 Mpc ( $H_0=100 \text{ km s}^{-1} \text{ Mpc}^{-1}$ ).

## 2. Global properties

The typical  $H_2$  masses, estimated from the CO integrated intensities, using a conversion ratio  $N(H_2)/I_{CO}=2 \cdot 10^{20} \text{ cm}^{-2} (\text{K km s}^{-1})^{-1}$ , fall between  $10^7$ - $10^9 M_\odot$ . Since we have used a conservative conversion ratio and a large Hubble constant, these mass estimates can be regarded as lower limits to the molecular masses as long as the CO emission is optically thick.

The far-IR luminosities of the early type galaxies are, on average, an order of magnitude lower than for a sample of 121 spiral galaxies (including field and interacting systems). The spiral sample have been compiled from the literature and the relevant parameters are transformed to the same conversion ratio  $N(H_2)/I_{CO}$  and the same Hubble constant as the early type sample. The current star formation rate for the early type galaxies, assumed to be proportional to the far-IR luminosity, are typically  $0.1 - 1 M_\odot \text{ yr}^{-1}$ , i.e. an order of magnitude lower than for spiral galaxies. The distribution of the ratio of 60 mm and 100 mm IRAS fluxes shows that the dust temperatures of the early type galaxies are similar to those of the spiral sample, indicating that the heating mechanism is of similar efficiency for both samples. The star formation efficiencies have been estimated through

the ratio of far-IR and CO luminosities, and have been found to be similar for the early type and spiral samples. Furthermore, weighting the far-IR and CO luminosities with their temperature dependences ( $T^5$  and  $T$ , respectively), we find a linear correlation between these quantities. These results imply that the presence of spiral arm density waves is not necessary for efficient formation of massive stars on a global scale. The presence of massive molecular cloud complexes in these early type galaxies implies that spiral density waves are not necessary for molecular cloud formation either.

The ratio  $L_B/L_{FIR}$ , measuring the ratio of star formation rates averaged over approximately  $10^9$  and  $10^6$  years, indicate that the star formation history of the early type galaxies are similar to the spiral galaxies, i.e. more or less constant over time periods of at least  $10^9$  years.

## 3. Individual sources

We have mapped some early type galaxies in more detail, using both the  $^{12}\text{CO}(1-0)$  and  $(2-1)$  transitions, as well as observing  $^{13}\text{CO}(1-0)$  and  $(2-1)$ . Here we present results for the lenticulars NGC 404, NGC 3593 and NGC 4369.

**NGC 404.** This peculiar S0 galaxy with a previously unknown distance has the molecular gas distributed in a broken ring close to the nucleus. The gas seems to be situated in the plane of the disk. Our CO observations together with observations of the HI content, using the VLA, indicate that NGC 404 is situated at a distance of approximately 10 Mpc. The total  $H_2$  mass is estimated to be  $7 \cdot 10^7 M_\odot$ . The star formation rate, derived from the far-IR luminosity, is found to be  $0.2 M_\odot \text{ yr}^{-1}$ , which is less than the estimated rate of return of

processed stellar material to the interstellar medium. The  $^{12}\text{CO}(2-1)/(1-0)$  line intensity ratio is found to be about 0.8. From a  $^{13}\text{CO}(1-0)$  observation we estimate the optical depth of the  $^{12}\text{CO}$  line to be 10

**NGC 3593** This edge-on S0 galaxy has the molecular gas distributed in a disk-like configuration. The total molecular mass is found to be  $2 \cdot 10^9 M_\odot$ , with an assumed distance of 11 Mpc. The  $^{12}\text{CO}(2-1)/(1-0)$  line intensity ratio is close to 1. Together with a  $^{13}\text{CO}(2-1)$  observation this result indicates that the  $^{12}\text{CO}$  emission is optically thick with an excitation temperature  $>15-20$  K. The kinematical properties of the molecular gas indicate solid body rotation out to a distance of 0.8 kpc from the nucleus and constant rotational velocity at larger distances.

**NGC 4369** This face-on S0 galaxy has the molecular gas distributed in a bar-like structure in the center region. The iso-velocity contours run parallel to the bar. The total molecular mass is estimated to be  $2 \cdot 10^8 M_\odot$ . The  $\text{CO}(2-1)$  and  $(1-0)$  distributions indicate that the line intensity ratio vary over the face of the galaxy. The  $(2-1)$  and  $(1-0)$  observations were done simultaneously thus eliminating pointing offsets as the cause for this effect. Whether this varying line ratio is due to different optical depths or excitation temperatures over the face of the galaxy is not known at the present since we do not yet have  $^{13}\text{CO}$  observations of this galaxy.

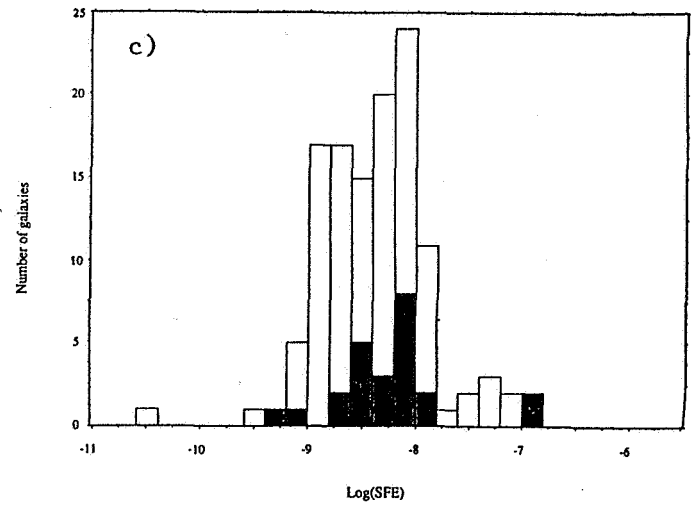
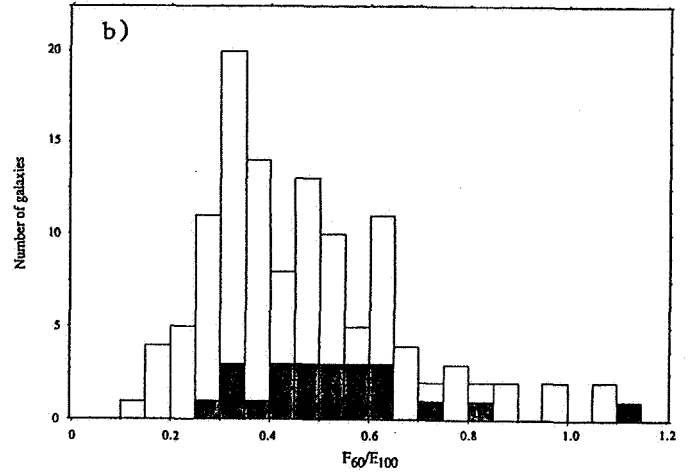
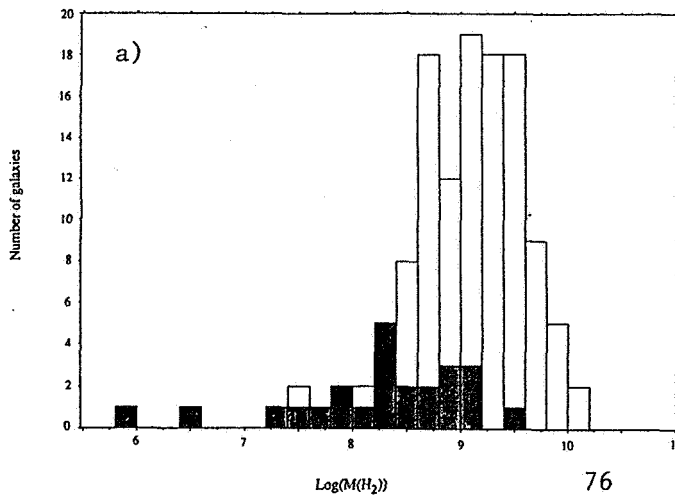


Figure 1. The distributions of a)  $\log(M(\text{H}_2))$ , b)  $F60/F100$ , and c)  $\log(\text{SFE})$  for the early type galaxies (dark bars) and the spiral sample (unfilled bars).



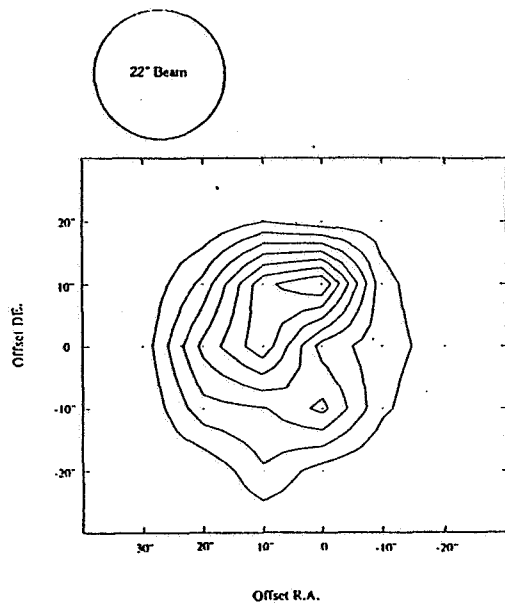


Figure 2. The  $^{12}\text{CO}(1-0)$  integrated intensity distribution in NGC 404. The map spacing is  $10''$ . The lowest contour is  $3.5 \text{ K km s}^{-1}$ , and contours are spaced  $1.5 \text{ K km s}^{-1}$  apart.

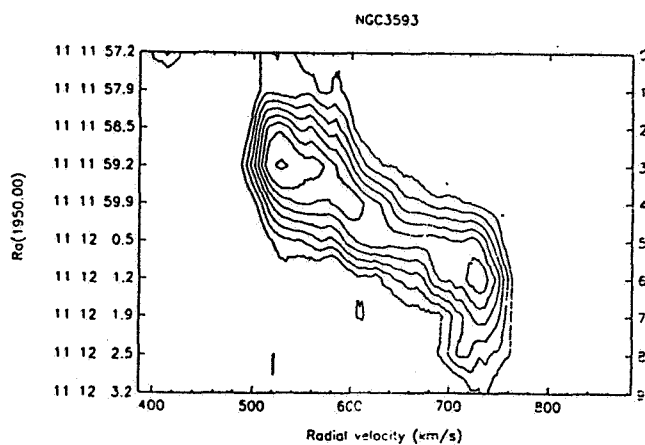


Figure 3. A position-velocity diagram along the major axis of NGC 3593.

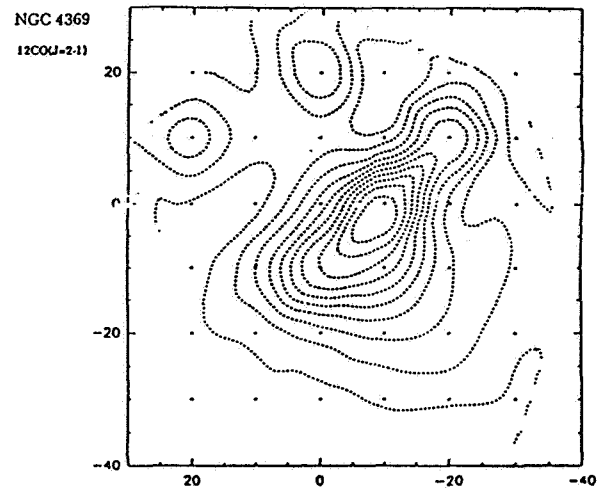
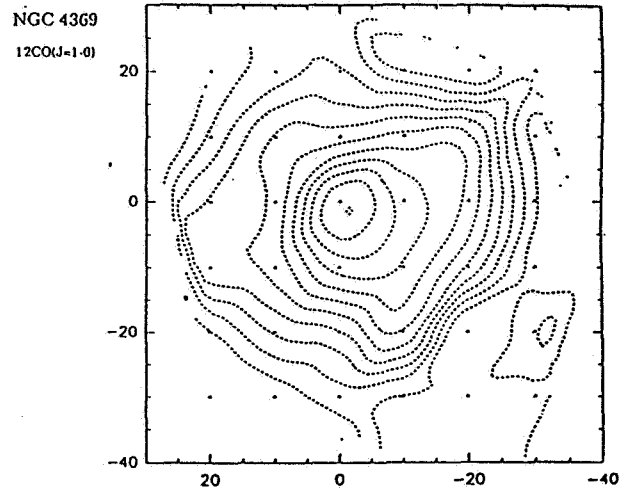


Figure 4. The  $^{12}\text{CO}(1-0)$  and the  $^{12}\text{CO}(2-1)$  integrated intensity distributions for NGC 4369.